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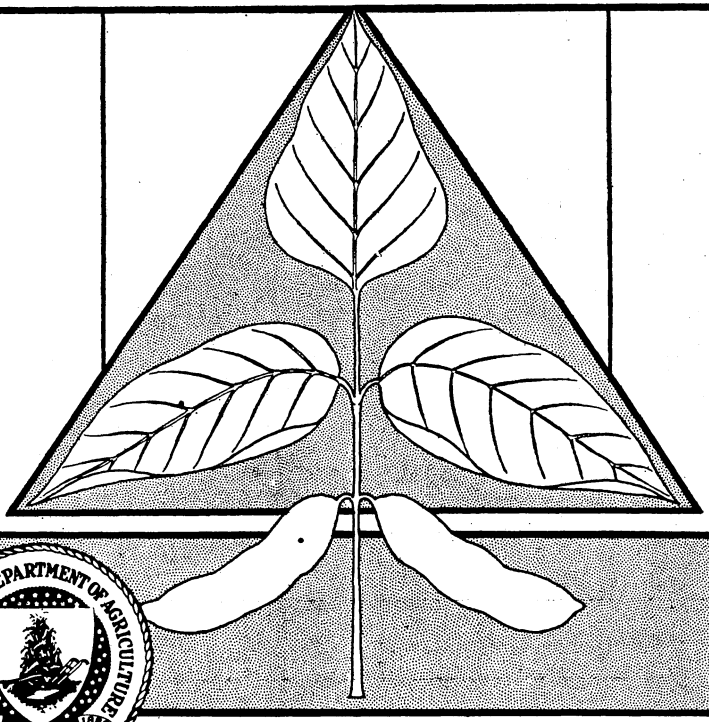
U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1617

SOYBEAN UTILIZATION



EXTENSIVE UTILIZATION of the soybean for forage and the increased use of the beans for oil and meal and for human food have resulted in a phenomenal increase in acreage and production of the crop. By reason of its variety and the palatability of the forms in which it can be served, the soybean is a very desirable article of human food, and its use as such is gradually increasing.

The feeding value of soybean seed compares favorably with that of other concentrated feeds. The growing of seed for feeding will produce, at a moderate cost, at least part of the high-protein concentrates necessary for stock feeding and milk production.

Soybeans, in addition to their forage and food value, contain a valuable oil which is utilized to a very considerable extent in Asiatic countries, in Europe, and in North America.

Soybean hay can be fed profitably to all kinds of livestock. It makes an excellent winter ration for young cattle, sheep, horses, and mules, and may be used to good advantage for hogs and poultry.

As a pasture crop the soybean is valuable for all kinds of livestock. The most profitable method is to pasture with hogs, supplementing with a corn ration. The crop furnishes a very satisfactory pasture in late summer and early fall when perennial pasture may be short.

The soybean is a useful supplement to corn for silage, which is readily eaten by stock and produces no bad effects on the quality of milk and its products.

The fertilizing value of a crop of soybeans compares favorably with that of other legumes commonly grown for green manure.

Straw obtained from threshing soybeans has value as roughage for wintering dry dairy cows and beef cattle. It is also a good roughage for sheep.

Much of the information given in this bulletin is a review of the work of the State agricultural experiment stations.

For information on culture and varieties of soybeans and the production of hay and seed the reader is referred to the following Farmers' Bulletins:

No. 1520, Soy Beans: Culture and Varieties.

No. 1605, Soy-Bean Hay and Seed Production.

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SOYBEAN UTILIZATION

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INTRODUCTION

THE WIDESPREAD INTEREST in the soybean, created by the phenomenal increase in acreage and production, indicates that the crop is destined to become one of considerable economic value in the United States. Within a decade it has advanced from a position of minor to one of major importance. Whereas previously it was grown occasionally, usually as a substitute crop when clover or some other crop had failed, at the present time the soybean occupies a permanent place in many of the rotations of the farming systems of the eastern half of the United States. With its wide range of uses and numerous varieties, its production is no longer localized and its increasing importance is assured. The soybean is the most important legume grown in Asiatic countries in the scope of its utilization and value. It is grown primarily for the beans, which are used to a very large extent in the manufacture of numerous products for human food. The beans are also extensively utilized, especially in Manchuria, in the production of oil and meal.

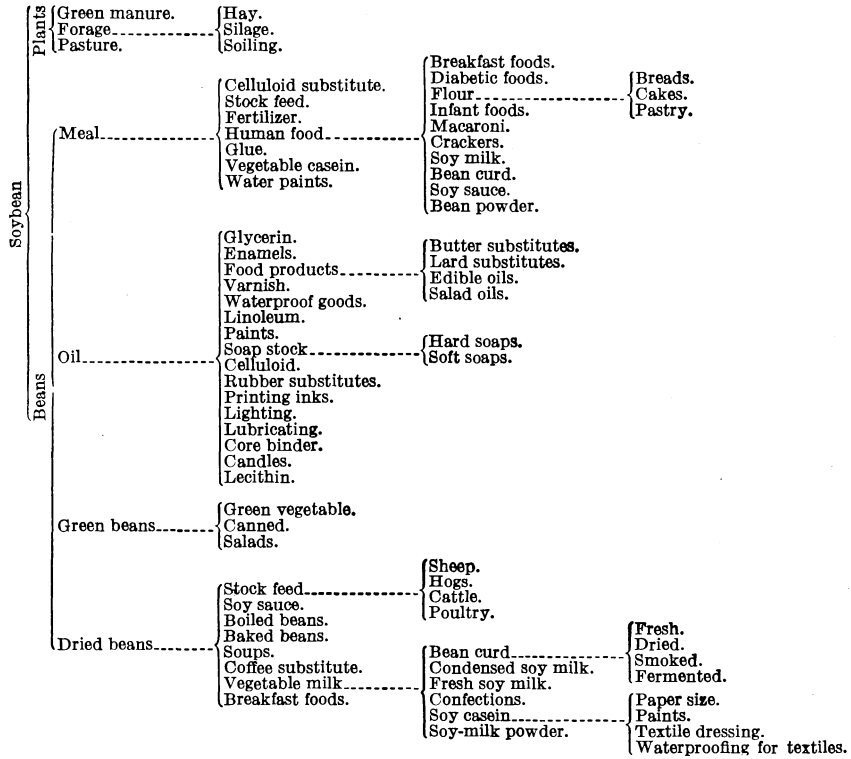
The soybean is used in the United States primarily for forage purposes, being preserved either as hay or silage or cut and fed green as silage, and it is also pastured extensively with hogs and sheep. Occasionally it is used as a green manure or summer cover crop in orchards. Although it will no doubt continue to grow in use as a forage crop, indications are that the future increase in acreage will be largely for the production of beans.

Unlike the seed of most other legumes, that of the soybean is rich in oil, which makes the crop an important source of vegetable oil and meal. Several mills in the Mid-Western and Southern States are now crushing domestic-grown beans for oil and meal, and other mills are being built or equipped for this purpose.

The value of the soybean and its products, and their industrial uses, together with methods of converting soybeans into proper form for such uses, are being extensively studied. The commercial

possibilities of the soybean and its products offer a potential outlet for a supply of beans many times the present surplus above seeding requirements. The extent of commercial utilization seems to be limited chiefly by the supply of the raw product.

The following outline shows the manifold uses to which the soybean may be put. Few other plants are useful in so many ways.



SOYBEANS FOR HUMAN FOOD

The soybean has been utilized for many centuries by the people of oriental countries in the preparation of numerous fresh, fermented, and dried food products which form an indispensable part of their diet. The various soybean food products not only give flavor and relish but furnish to a very considerable extent the protein that in the diet of the western people is supplied largely by meats. Some of these preparations are eaten by oriental people at every meal and by rich and poor alike. Shoyu or soy sauce is the only one of these oriental products that has been introduced to any extent into other countries.

The importance of legumes is becoming more generally recognized as an economical source of protein. In view of the richness in nutrient constituents, the extent to which these are assimilated by the body, and the numerous products to be prepared, the soybean deserves high rank as an important food material. Investigations of the nutritive efficiency of the soybean have shown that it contains

both the water-soluble and the fat-soluble vitamins. It contains at the most but a slight trace of starch. Extensive experiments in North America and Europe indicate its value as the basis of food for persons requiring a low starch diet, and for many years food companies have had on the market forms of soybean flour prepared for persons requiring a diet of this kind. Extended investigations show that soybean flour as a gruel is a most valuable food in the dietary of infants.

In North America the soybean has attracted attention at various times as an article of food, but thus far it has been little used. Attempts have been made at various times to use it in the manner of field and navy beans, but with little success. Several food manufacturers have recently begun the manufacture of different foodstuffs such as soy sauce, soybean flour, breakfast foods, and edible

FIGURE 1.—Steamed soybeans in the preparation of miso, a popular Japanese food

oil, from the soybean and its products, oil and meal. Undoubtedly some of the soybean products of the Orient may meet with increasing favor in North America, but prejudice and custom are among the factors that prevent a people from quickly adopting new foodstuffs.

DRIED BEANS

The mature or dried beans of the yellow-seeded varieties may be used after the manner of navy or other beans in making numerous palatable and nutritious dishes. Because of their high fat content and compact texture, most varieties of soybeans do not cook so readily as the navy or field bean. The Easycook and Hahto varieties, however, cook fully as soft as other beans. In China and Japan the dried or mature soybean is seldom used for boiling or baking but is an ingredient in numerous fermented products such as miso and natto (fig. 1). When properly roasted and prepared, the soybean makes an excellent cereal beverage, and it has been used at various times in the United States as a coffee substitute. It was at one time sold as "coffee bean." In oriental coun-

tries soybean coffee substitute is a commercial product. In China the beans are soaked in salt water and then roasted, the product being eaten after the manner of salted peanuts.

GREEN OR VEGETABLE BEANS

When soybeans are about fully developed the beans make a most palatable and nutritious green vegetable, being used in the same manner as the green pea or the Lima bean. The pods are tough and not desirable, but if boiled from 5 to 10 minutes the shelling of the beans will be facilitated. The Hahto and Easycook varieties have been found especially valuable for use as green beans.

SOYBEAN FLOUR

Soybean flour is made by grinding either the whole bean, preferably yellow-seeded varieties, or the press cake after the oil has been removed from the beans. In invalid and infant dietetics soybean flour has been used for many years in the United States, although as yet it is not a common commercial product. Extensive tests show that the flour can be successfully used in the making of bread, muffins, biscuits, crackers, and gems. (Fig. 2.) About one-fourth soybean flour and three-fourths wheat flour is the proper proportion. This addition of soybean flour gives a more nutritious article of food with a rich nutlike flavor. In some of the pastry products as much as one-half soybean flour can

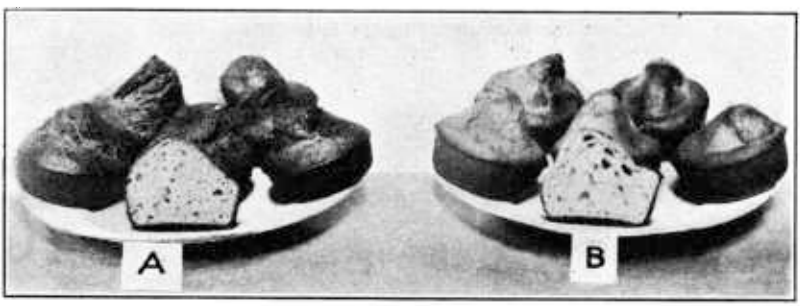


FIGURE 2.—Muffins made from equal parts of soybean and wheat flour (A) and from wheat flour (B). Soybean flour may be successfully used as a constitutent for bread and muffins with about one-fourth soybean flour and three-fourths wheat flour as the proper proportions

be used. When a special food of low starch content is desired, as for diabetic persons, a larger proportion of soybean flour is used with some form of gluten substituted for the wheat flour. On account of its high food value, as well as the palatable products made from it, soybean flour is finding increasing favor as a foodstuff in North America and Europe.

SOYBEAN OIL

One of the principal uses of soybean oil in the Orient, chiefly in China, is for food. It is consumed largely in the crude state by the poorer classes, but among the rich it is boiled and allowed to stand until clarified. Experiments show that soybean oil compares very favorably with the more common culinary table oils with respect to the thoroughness with which it is assimilated. After refining and deodorizing, it is used extensively in the production of salad and cooking oils and in the manufacture of lard and butter substitutes.

SOY SAUCE

Soy or shoyu sauce is a dark-brown liquid prepared from a mixture of cooked and ground soybeans, roasted and pulverized wheat (barley is sometimes used), salt, and water. This mass is inoculated with a culture known as rice ferment (*Aspergillus oryzae*) and left from 6 to 18 months in vats or casks (fig. 3) to ferment. Soy sauce is largely used by oriental peoples in cooking, as a relish or condiment to increase the flavor and palatability of the diet, and

as an aid in the assimilation of food. One factory in the United States manufactures soy sauce from domestic-grown beans and has found a large commercial outlet throughout the country.

SOYBEAN SPROUTS

Soybeans and several other species of beans are sprouted and used as a green vegetable by the Chinese. Sprouted soybeans may be used in various dishes as a home winter vegetable.

SOYBEAN VEGETABLE MILK

If the dried beans, preferably yellow-sceded varieties, are soaked for a few hours, then finally crushed (fig. 4) and boiled for about 30 minutes in the proportion of 3 parts of water to 1 part of mash, a milky emulsion is obtained which is very similar in appearance and properties to animal milk. This liquid, separated out by means of a very fine sieve or cloth strainer, is the soybean or vegetable milk used so extensively in China. Soybean meal after the oil is extracted or whole soybean meal may be utilized quite as well as the whole

FIGURE 3.—Chinese courtyard with pots of fermented soybeans and brine from which the well-known soy sauce is made

bean. In the absence of animal milk, soybean milk is used extensively in the fresh state and as the basis of various kinds of vegetable cheeses in oriental countries. Soybean milk in the form of a powder is a commercial product in some European countries, and in parts of the United States it has been used in special feeding cases. Attempts have been made to manufacture the milk powder on a commercial scale. The milk can be used successfully in numerous preparations, such as breads and cakes, in creaming vegetables, in milk chocolate, and in custards.

After separating the liquid from the solid material, the residue is still very rich in nutritive substances and can be dried and used for cattle feed or made into flour for human food.

SOYBEAN CURD

The addition of magnesium or calcium salts or of rennet or lactic acid to soybean milk when hot precipitates some of the protein, forming a grayish white curd which settles out, leaving a yellowish watery liquid. This curd, after being drained and pressed, represents bean curd or tofu (fig. 5), which is extensively eaten and forms the basis of numerous fermented, smoked, and

dried cheeses in China and Japan. Bean curd is made fresh daily and is a staple article of diet among oriental peoples. In many cities of the United States having a large oriental population fresh bean curd may be found in the Chinese and Japanese markets. Attempts to place canned bean curd on the market have met with but little success. Bean curd is a highly nutritious food and no doubt could be elaborated by the American housewife into a variety of palatable dishes.

SOYBEANS FOR LIVESTOCK

The efficiency of soybeans as a nitrogenous feed for all kinds of livestock is indicated by extensive feeding trials and practical experience. The beans can be used as a protein supplement to replace at least partially the expensive commercial protein concentrates necessary for stock feeding and milk production. The growing of

FIGURE 4.—Grinding soybeans with a stone mill in the manufacture of soybean milk in China

soybeans will enable the farmer to produce at moderate cost at least part of these high-protein feeds.

The beans contain from 30 to 46 per cent protein and thus compare favorably with other concentrated feeds. When fed to sheep and hogs, the beans can be fed whole, but in general it is preferable to crack or grind them. Practical experience has shown that it is advisable first to mix the beans with corn, oats, or peas and then grind them together into meal, as the soybeans are difficult to grind alone because of their high fat content. Owing to the high content of protein, soybeans should always be fed in mixture with a less

concentrated feed. The amount of digestible nutrients in soybeans in comparison with other concentrated feeds is shown in Table 1.

TABLE 1.—*Analyses of soybeans and other concentrates* [1]

Feeding stuff	Moisture	Ash	Crude protein	Carbohydrates		Fat or ether extract	Digestible protein	Digestible carbohydrate equivalent [2]
				Crude fiber	Nitrogen-free extract			
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Soybeans (seed)	6.4	4.8	39.1	5.2	25.8	18.7	35.6	60.4
Cottonseed meal (choice)	7.1	5.7	41.7	10.0	28.4	7.1	35.0	40.7
Linseed meal (new process)	10.4	5.5	36.1	8.4	35.6	3.9		
Wheat middlings	10.1	3.5	16.3	4.3	61.6	4.2	13.2	60.1
Wheat bran	9.6	5.9	16.2	8.5	55.6	4.2	12.5	48.7

[1] Analyses compiled by the Bureau of Chemistry and Soils.
[2] The carbohydrate equivalent shown is the sum of the digestible crude fiber and nitrogen-free extract, plus 2.25 times the digestible fat.

SOYBEANS FOR SWINE

Extensive feeding tests have shown the soybean to be one of the cheapest sources of protein grown on the farm for balancing a

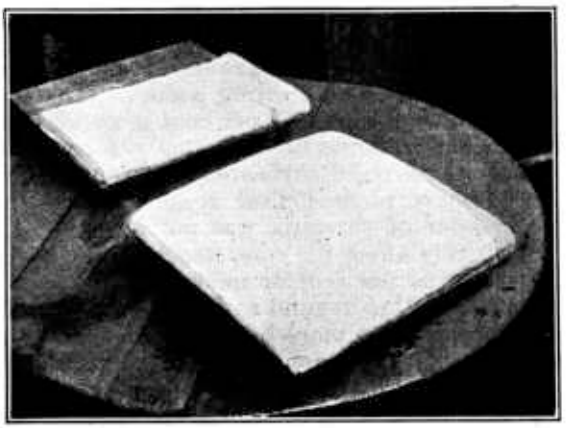


FIGURE 5.—Blocks of freshly made bean curd, "tofu," as sold in the markets in the Orient

ration of corn for fattening hogs. As a supplement to corn meal for growing and fattening pigs, the Wisconsin Agricultural Experiment Station found that ground soybeans proved about 10 per cent superior to wheat middlings, figuring the cost of the feeds as the same. The Delaware station in a feeding test of the relative value of soybeans as protein supplements for fattening pigs found ground soybeans not so efficient as tankage for pork production, but the addition of bone meal considerably improved the efficiency of the soybeans. Experiments carried on at the Indiana station show that when a mineral mixture consisting of superphosphate (acid phosphate), wood ashes, and salt is combined with a ration of soybeans and corn, excellent and economical results in pork production are obtained.

Previous results from feeding soybeans with corn were unsatisfactory.

At the Ohio station experiments in which raw and cooked soybeans and soybean meal were compared with tankage as supplements to corn for fattening hogs showed that the corn and tankage rations gave slightly better results than the raw soybean ration without corn. However, when cooked soybeans were fed with minerals the gains exceeded those made by tankage. Other feeding tests were conducted in which fattening swine in dry lot had access to five varieties of soybeans together with corn and minerals. The different varieties of soybeans were kept in separate compartments of a self-feeder and the shoats had equal access to all varieties. The test showed that these varieties ranked in the following order of palatability: Midwest (yellow), Hamilton (brown), Manchu (yellow), Ebony (black), and Wilson (black).

SOYBEANS FOR DAIRY CATTLE

In feeding tests with dairy cows at the Iowa station, cracked soybeans proved to be worth $60 a ton when old-process linseed meal was worth $45 a ton for feeding milk cows. Soybeans were therefore a valuable supplement to a home-grown ration of corn silage, alfalfa hay, cracked corn, and ground oats. The soybeans were palatable and had no deleterious effects on the animals.

In comparing the relative value of ground soybeans and cottonseed meal for milk production, the Tennessee station found the two feeds to have about the same feeding value. The South Dakota station found ground soybeans 17.7 per cent more efficient than old-process linseed meal for butterfat and 19.9 per cent more efficient for milk production. Ground soybeans were found to be as palatable and gave as good physiological results as the linseed meal, and the flavor or odor of the milk was not affected. Ground soybeans do not noticeably affect the consistency of the butter until the grain ration contains 50 per cent or more soybeans.

At the Mississippi station ground soybeans produced 3.64 per cent less milk and 11.65 per cent more butterfat than an equal quantity of cottonseed meal. Ground soybeans were found to be slightly superior to soybean meal for milk and butterfat production. The Indiana station also found that ground soybeans gave better results than either soybean meal or linseed meal for milk production. In feeding tests conducted at the Delaware station in which soybean meal and ground soybeans were compared with peanut meal, the milk production proved about 2 per cent greater during the peanut-meal periods than during the ground soybean periods, indicating a very high feeding value for ground soybeans when used as a protein supplement in the dairy ration. A desirable effect of the ground soybeans in the ration was that the cows maintained their body weight much better during the ground soybean periods than during the peanut-meal periods. In fact the cows gained considerable weight during the periods of ground soybean feeding.

SOYBEANS FOR BEEF CATTLE

In feeding tests at the Indiana station, whole soybeans as a substitute for cottonseed meal gave satisfactory results with 2-year-

old steers. The rate of gain was as rapid and the finish was as good. It was also found that the gains made by hogs following steers were materially influenced by the protein concentrate fed to the cattle.

SOYBEANS FOR SHEEP

In feeding trials with sheep at the Wisconsin station, soybeans produced larger gains and a heavier clip of wool than whole oats for a given amount of feed. Results indicate that soybeans are an economical supplement to corn for gains with sheep. At the Ohio station feeding tests indicate that for fattening lambs ground soybeans can be used to replace linseed meal as the protein concentrate in a ration of corn, alfalfa hay, and corn silage. As shown by the finish on the lambs and the profit per head, coarsely ground soybeans, after a grinding charge of 10 cents per hundred pounds was added, gave slightly more economical results than whole soybeans. The Indiana station found that soybeans may be used as a substitute for cottonseed meal in rations for fattening lambs. The average of three trials showed that gains made from the soybeans were made at as rapid a rate and at no greater expenditure of feed than when cottonseed meal was fed.

SOYBEANS FOR POULTRY

It has been demonstrated quite conclusively that soybean protein is a valuable nitrogenous food and may be used to good advantage in poultry rations. When used for poultry it is necessary, however, that the soybean ration be supplemented with a suitable mineral mixture. Many farmers have found that after soaking or cooking the whole beans are more readily eaten by poultry. At the Indiana station ground whole soybeans were found as satisfactory as soybean meal when used in place of tankage in a laying mash, provided a mineral mixture was added.

SOYBEANS FOR OIL

In addition to their forage and food value, soybeans contain a valuable oil which is utilized to a very considerable extent in Asiatic countries, in Europe, and in North America. In Manchuria the soybean is largely grown for oil (fig. 6) and meal and is always relied upon by the Manchurian farmer as a cash crop. It constitutes a staple product of Manchurian agriculture and occupies about 25 per cent of the total cultivated land. Previous to the Russian-Japanese war, China and Japan were not only the greatest producers, but were also the greatest consumers of the soybean and its products. About 1908 the first successful importations of soybeans from Manchuria were received in Europe and North America. The beans were utilized by extracting the oil, which was found valuable for various industrial purposes, leaving the bean cake or meal as a stock feed. As the value of the oil and meal became recognized, new uses and markets were found and the trade in the soybean and its products became one of great importance, until now it has assumed such large proportions that the soybean has become an important competitor of other oil seeds.

The first extensive use of the soybean in the United States for oil was about 1910, when an oil mill on the Pacific coast used beans imported from Manchuria. Although many efforts have been made during the past 20 years to interest cottonseed-oil mills of the Southern States in the utilization of domestic-grown soybeans for oil, no extensive work was done until the latter part of 1915. A shortage of cottonseed in the South at that time and a surplus of soybean seed in North Carolina led several cottonseed-oil mills in that State to enter upon an extensive production of soybean oil and meal. Increased interest in the use of the soybean for livestock and human food at that time brought about a large demand for seed and consequent high prices, which made the crushing of domestic soybeans unprofitable. As a result, during the following two or three years soybeans were imported from Manchuria and crushed

FIGURE 6.—Loading soybean oil in tanks at a soybean oil mill, Harbin, Manchuria

by several southern cottonseed-oil mills. Since about 1923 soybean production, especially of the more generally grown varieties, has increased to such an extent that a saturation point has been reached in the supply of seed required for planting. Several soybean-oil plants have been built in the Middle Western States, and a few cottonseed-oil mills in the South are again crushing domestic-grown soybeans.

The utilization of the soybean and its products in industries is practically new but appears to have many possibilities. The crop is now of great value to American agriculture, especially in the Corn and Cotton Belts, not only as a cash crop for oil production but as a green-manure and pasture crop or for maintaining the fertility of the soil. The large annual importation of soybeans, soybean oil, and soybean cake into the United States, as shown in Table 2, indicates a ready market for these products.

TABLE 2.—*Quantity and value of soybeans, soybean cake, and soybean oil imported into the United States, 1910 to 1928, inclusive*[1]

Year	Soybeans		Soybean cake		Soybean oil	
	Quantity	Value	Quantity	Value	Quantity	Value
Fiscal year:	*Pounds*	*Dollars*	*Pounds*	*Dollars*	*Pounds*	*Dollars*
1910					Not stated.	1,019,842
1911					41,105,920	2,555,707
1912					28,021,282	1,577,131
1913			7,004,803	93,002	12,340,185	635,888
1914	1,929,435	49,507	3,163,260	38,255	16,360,452	830,790
1915	3,837,865	87,306	5,975,592	64,307	19,206,521	899,819
1916	3,003,065	78,963	10,468,001	103,081	98,119,695	5,128,200
1917	5,344,334	132,572	11,760,935	136,064	162,690,235	11,410,606
1918	31,812,997	692,964	586,820	9,964	336,824,646	32,827,460
Calendar year:						
1918	1,433,349	111,818	78,370	1,261	335,984,148	38,454,730
1919	4,368,780	201,496	16,988,787	483,221	195,808,421	24,019,226
1920	3,136,850	180,759	24,473,132	645,267	112,213,750	13,721,422
1921	3,946,173	136,760	10,637,420	183,708	17,282,967	700,833
1922	3,536,807	145,075	4,282,420	87,683	17,294,094	1,013,172
1923	3,648,243	147,559	31,223,638	545,297	41,679,110	2,680,200
1924	4,184,120	152,579	47,084,672	895,869	9,125,158	623,798
1925	3,811,897	150,780	27,801,936	535,800	19,492,900	1,507,219
1926	3,727,628	148,099	42,869,187	885,013	30,711,687	2,150,923
1927	4,189,168	162,642	53,950,898	1,014,239	14,914,792	887,747
1928	4,255,734	154,579	96,810,135	1,920,021	13,116,220	823,619

[1] Compiled from Foreign Commerce and Navigation of the U. S. Department of Commerce.

METHODS OF PROCESSING BEANS FOR OIL

The introduction of the soybean into the Western World for oil purposes has not made any marked changes in the equipment of the modern oil mills. The methods used in the extraction of oil from soybeans are similar to those used with other oil seeds, as cottonseed, linseed, and peanuts. In Manchuria the manufacture of oil and cake has not been confined to large centers, as every center of bean production has its native mill in which the method of extraction is decidedly primitive. In the last decade, however, large bean mills equipped with modern machinery have been erected at important centers of soybean production throughout Manchuria.

Different processes or methods are used in the manufacture of oil from the soybean. The oldest method of oil processing is that by expression, in which the hydraulic press or expeller is used. The hydraulic process is widely used in processing cottonseed in the South and linseed in the Northern States, but the expeller process is coming into more general use, especially where mills are being equipped solely for soybeans.

The other method of processing is by extracting the oil from the ground beans by some chemical solvent such as benzol, naphtha, or ether. The oil is then obtained by evaporating the solvent, which is distilled and used over again. The residue is well dried and is said to contain no detectable trace of the solvent. By this process nearly all of the oil is extracted, only 0.5 to 1.5 per cent of oil remaining in the meal. It is contended that more oil is obtained by this process and that the meal is well suited for flour, feed, or fertilizer, as it contains less oil. Meal or cake made by the expression methods, hydraulic and expeller, contain from 5 to 9 per cent of oil.

Extensive tests with domestic beans show that 1 ton of beans (33⅓ bushels of 60 pounds each) containing 19 per cent oil will

yield by the expression method, about 250 pounds of oil and about 1,600 pounds of meal, and about 150 pounds is lost in cleaning, in milling, and in moisture.

UTILIZATION OF SOYBEAN OIL

Soybean oil belongs to the group of drying oils and stands midway in its properties between linseed oil and the semidrying cottonseed oil. Considerable variation, however, occurs in its drying qualities as well as in its color, odor, and taste, depending upon the source and variety of the bean, upon the care exercised in packing and transporting both the beans and the oil, and upon the oil-processing method. Soybean oil can be used as a substitute for either linseed or cottonseed oil, especially in soap making. In the manufacture of soft soap, soybean oil serves as an almost complete substitute for linseed oil, but unless it is hydrogenated it can but partially replace cottonseed oil in the manufacture of hard soaps.

In Europe and North America, paint manufacturers are using soybean oil as a substitute for part of the linseed oil in certain kinds of paint. Soybean oil, when properly refined, loses its characteristic "beany" flavor and can be used in the manufacture of lard substitutes, in margarine, and as a salad oil. As the process of refining is perfected there seems to be scarcely any use for which soybean oil can not be used in the manufacture of foodstuffs in which oil has a part. Other trade uses of soybean oil are in the manufacture of linoleum, rubber substitutes, core binder, lecithin, and glycerin. With the rapid growth of the soybean industry, many new trade uses for the oil have been found, and it has become an important competitor of other vegetable oils. One of the principal uses of soybean oil in Asiatic countries, chiefly China, is for food. The oil is also used in the Orient in the manufacture of foodstuffs, soap, varnish, printing ink, paints, candles, waterproof goods, and for lighting and lubricating.

SOYBEAN MEAL[1]

Soybean cake or meal remaining after processing the beans for oil is a most valuable product and has the widest usefulness. In European countries and in North America soybean meal is used almost entirely for feeding purposes. It is highly concentrated and nutritious and is relished by all kinds of livestock. In oriental countries (fig. 7) it is used very extensively for fertilizing purposes, but is also recognized as a valuable feed for work animals and for fattening stock. The use of the meal as a flour for human food is becoming increasingly important in Europe, in North America, and in the Orient.

SOYBEAN MEAL FOR HUMAN FOOD

The meal remaining after the oil is taken from yellow-seeded varieties of soybeans is bright yellow in color when fresh and has a sweet, nutty flavor. The use of this meal as flour for human food has become an important factor in several European countries during

[1] By soybean meal is meant the meal or cake left after expressing or extracting the oil from the beans. Also known as soybean cake.

the past few years and to some extent in North America as a food of low-starch content.

SOYBEAN MEAL FOR STOCK FEED

Practical experience supplemented by extensive feeding experiments in the United States and in several European countries indicates the high feeding value of soybean meal for all kinds of farm stock. Alleged injurious effects from feeding it have been reported in the United States and in Europe, but after careful investigation no proof is to be had substantiating these reports. To avoid digestive troubles that may result from the high content of protein, it should be fed with the same precautions observed with other highly concentrated feeds. The digestibility of soybean meal com-

FIGURE 7.—Soybean cake awaiting shipment at a Manchurian port

pares very favorably with that of other oil meals. Table 3 gives analyses of soybean meal in comparison with other similar concentrated feeds.

TABLE 3.—*Analyses of soybean meal and other important oil meals* [1]

Kind of oil meal	Constituents (per cent)					
	Moisture	Protein	Fat	Nitrogen-free extract	Ash	Fiber
Soybean	7.59	44.65	8.77	27.12	5.89	5.96
Cottonseed	6.62	40.29	7.41	28.63	6.21	10.84
Linseed (old process)	8.98	33.23	7.20	36.51	5.40	8.68
Linseed (new process)	9.63	37.51	2.49	36.09	5.54	8.74
Peanut (decorticated)	10.73	46.84	7.91	24.34	4.89	5.29
Sunflower seed	7.68	23.80	7.94	27.49	5.03	28.06

[1] Average analyses as reported by the Cattle Food and Grain Investigations Laboratory, Bureau of Chemistry and Soils.

SOYBEAN MEAL FOR SWINE

At the Ohio station soybean meals, resulting from the different methods of processing soybeans for oil, showed wide variations in their value for supplementing corn for pigs. The results indicate that meals made by the expeller and hydraulic expeller processes are superior to solvent oil meals, which often have a beanlike color, odor, and taste. In stating the value of mineral supplements to corn and rape pasture, the same station found that 2 pounds each of ground limestone and bone meal saved 30.3 pounds of corn, 0.4 pound of soybeans, and 0.3 pound of salt per 100 pounds of gain. Soybean meal as a supplement to corn produced more rapid gains than tankage or ground or cooked soybeans. At the North Carolina station soybean meal was eaten readily by pigs and produced satisfactory gains when used as a supplement to corn. More profit and better gains were secured, however, when soybean meal and fish meal were mixed together in equal quantities than when the soybean meal was fed as the sole protein supplement.

SOYBEAN MEAL FOR DAIRY CATTLE

Extensive feeding experiments have been conducted in the United States and several European countries comparing soybean meal and soybean cake with cottonseed meal and linseed meal as a protein supplement in the dairy ration. Soybean meal has been found equal or superior to cottonseed meal and linseed meal for milk and butterfat production. At the Indiana station it was found that soybean meal had a feeding value for milk production equal to that of linseed meal. At the Delaware station results obtained showed that in feeding soybean meal and ground soybeans as protein supplements in the dairy ration a pound of digestible protein in ground soybeans was more efficient for milk production than a pound of digestible protein in soybean meal. Because of the high protein content of soybean meal it has a higher value per ton than ground soybeans, as much of the oil has been removed. At the same station it was found that 1 pound of digestible protein in peanut meal is 3 per cent more efficient for milk production than 1 pound of digestible protein in soybean meal, but with the higher protein content of the soybean meal the latter has a higher value per ton than peanut meal.

In feeding experiments at Copenhagen, Denmark, it was found that soybean meal, pound for pound, was just as effective for milk production as such other high-protein meals as cottonseed meal, peanut meal, and sunflower-seed meal. The Ohio station in comparing the value of soybean meal and linseed meal for milk production found the two practically equal, the difference being only 2 per cent in favor of the soybean meal. At the Mississippi station it was found that soybean meal maintained the milk flow equally as well as cottonseed meal, the amount of butterfat being slightly increased.

SOYBEAN MEAL FOR BEEF CATTLE

At the Indiana station a comparison between cottonseed meal, soybean meal, whole soybeans, and whole soybeans and mineral

mixture in the rations for winter steer feeding showed that the cattle receiving a ration with soybean meal made more economical use of their feed than the cattle on the other feeds. A comparison of cottonseed meal and soybean meal as protein supplements for use in fattening beef cattle at the Illinois station showed that the steers fed the soybean meal made somewhat faster and slightly more economical gains than those receiving the cottonseed meal, but the difference between the two feeds was not large enough to be of practical significance. Both feeds proved highly satisfactory, and from the results obtained it appeared that the two have practically the same feeding value. No difficulties were met in getting the cattle to eat the soybean meal.

SOYBEAN MEAL FOR POULTRY

With the rapid expansion of the soybean industry, poultrymen have at their disposal a new poultry feed that could well be used to much greater extent than is done at present. Poultrymen in the Pacific Coast States have used soybean meal for several years and consider it a most excellent feed for flesh and egg production. A number of feeding tests at various experiment stations have shown its value as a poultry feed, although proteins from a vegetable source have been generally considered inferior to proteins from an animal source. It has been shown that the addition of a mineral mixture increases the value of the soybean meal as a protein supplement for growth and egg production.

In extensive feeding tests for egg production at the Indiana station, soybean meal, when supplemented by the proper mineral mixture, proved to be a satisfactory source of concentrated protein and gave practically the same results as animal proteins. Other feeding tests were made at the Indiana station in which meat scraps were compared with soybeans as a supplement to corn for growing chicks. The results show that when the basal ration was supplemented with varying quantities of protein from meat scraps, soybean meal, or a combination of both, the best growth resulted from the addition of 10 per cent of protein derived from soybean meal.

At the North Carolina station it was found that a mixture of equal parts of soybean meal, wheat shorts, and cracked corn moistened with sweet milk was a good ration for little chicks.

SOYBEAN MEAL AS A FERTILIZER

The use of soybean meal as a fertilizer has been confined almost entirely to Asiatic countries. For centuries soybean meal has been sent to the sugar plantations of southern China, and its use has gradually spread to the plantations in Java and other tropical islands. The high fertilizing value of soybean meal has been long recognized by the Japanese, who import large quantities annually from China for use in the rice fields and as a manure for mulberry trees. In Manchuria large quantities are used annually on poor soils for both field and garden crops. Although large quantities of soybean meal have been imported into the United States and Europe during the last few years, but little has found its way into the manufacture of commercial fertilizers.

Like cottonseed meal, soybean meal contains some phosphorus and potash, a large proportion of which is available, but its principal value in fertilizers is as a source of nitrogen. The composition of soybean meal with reference to fertilizing constituents and a comparison with cottonseed meal are shown in Table 4.

TABLE 4.—*Fertilizing constituents of soybeans, soybean meal, and cottonseed meal*[1]

Product	Constituents (per cent)			
	Nitrogen	Ammonia	Phosphoric acid	Potash
Soybean (seed)	6.51	7.90	1.36	1.82
Soybean meal	7.24	8.79	1.44	1.86
Do.	7.72	9.37	1.36	1.82
Do.[2]	7.18	8.72	2.37	2.92
Cottonseed meal	6.79	8.24	2.88	1.77

[1] Analyses furnished by the Bureau of Chemistry and Soils.
[2] Solvent process meal.

MISCELLANEOUS USES OF SOYBEAN MEAL

Research chemists have been studying the value of soybean meal for industrial uses for many years, together with methods of converting it into proper form for such uses. Results indicate that the extent of possible commercial uses is limited principally by the supply of the raw product. Manufacturers of soy sauce in Japan have found from experiments that soybean meal will produce a soy sauce of better quality at a lower cost than the whole beans. Water paints, of which "solite" is a commercial product, are manufactured both in the Orient and in North America. Soybean meal has been successfully used in the manufacture of glue. Other products from soybean meal, either on a commercial basis or in the experimental stage, are size for paper, celluloid substitutes, vegetable casein, waterproofing for textiles, vegetable milk powder, and medicinal substances.

SOYBEANS FOR HAY

As indicated by the rapid increase in the soybean hay acreage during the last five years, one of the most common uses of the soybean is for hay. This hay can be fed profitably to all kinds of livestock, makes an excellent winter ration for young cattle, sheep, horses and mules, and has been used to good advantage for hogs and poultry. As a source of protein that can be produced on the farm to balance feeds for growing stock or for milk and butter production, soybean hay will reduce the quantity of high-priced concentrates that it is necessary to purchase. The feeding of soybeans alone is not to be advised as digestive troubles may result. The chief objection to the soybean for hay is that it has rather coarse, woody stems. This may be largely overcome by giving proper attention to time of harvesting, heavier rates of seeding, and by growing a good forage variety.

The principal value of soybean hay lies in its high content of digestible protein. As indicated by comparative feeding tests, it is

equal to red clover or alfalfa for milk and butter production. Table 5 shows that in its content of digestible nutrients soybean hay compares favorably with the hay of other important crops.

TABLE 5.—*Analyses of soybean hay in comparison with other important hay crops* [1]

Kind of hay	Moisture	Ash	Crude protein	Carbohydrates		Fat or ether extract	Digestible protein	Digestible carbohydrate equivalent [2]
				Crude fiber	Nitrogen-free extract			
Soybean	8.4	8.9	15.8	24.3	38.8	3.8	11.2	44.0
Cowpea	9.7	12.9	17.5	20.5	36.6	2.8	11.9	37.0
Alfalfa	8.3	8.9	16.0	27.1	37.1	2.6	11.5	42.0
Red clover	12.9	6.9	13.6	24.1	39.1	3.4	8.3	43.2
Timothy	12.5	5.4	6.8	28.3	44.3	2.7	3.3	44.7

[1] Analyses compiled by the Bureau of Chemistry and Soils.
[2] The carbohydrate equivalent shown is the sum of the digestible crude fiber and nitrogen-free extract, plus 2.25 times the digestible fat.

SOYBEAN HAY FOR DAIRY CATTLE

Soybean hay has been found particularly valuable for feeding dairy cattle. In a comparison of the feeding values of soybean and alfalfa hay at the Wisconsin station the milk production on the soybean ration averaged 1.1 pounds and the butterfat 0.02 pound less per cow than on the alfalfa ration. The weights of the cows were not so well maintained on the soybean ration as on the alfalfa ration. Equal quantities of feed were given each lot, but 18 per cent of the soybean hay was refused. In further feeding tests, cows fed soybean hay produced approximately the same quantity of milk and butterfat as cows fed alfalfa, but the cows on the soybean ration wasted more of their hay and gained only about one-half as much in body weight. Practically no difference was found in the production of milk from cows fed chopped and unchopped soybean hay. There was little waste in feeding the chopped hay, and chopping in this case increased its value 23 per cent.

At the Ohio station feeding tests to compare soybean with alfalfa hay as a source of protein in the production of milk showed that a large portion of the necessary protein can be supplied as economically by soybean hay as by high-priced concentrates. Experiments at the West Virginia station indicate that good soybean hay is superior to alfalfa hay as a feed for milk and butterfat production and for maintenance of body weight for milk cows, the results in this case differing from those obtained by the Wisconsin station.

In feeding tests with dairy cows at the Mississippi station soybean hay was found slightly superior to alfalfa hay for the production of butterfat and superior to Lespedeza hay for both milk and butterfat production. Hay of the Mammoth Yellow variety of soybeans was found superior to that of the Laredo variety for milk and butterfat production. Results obtained by the Pennsylvania station in feeding trials with soybean hay for milk production showed that soybean hay of poor or medium quality is inferior in feeding value to alfalfa hay, but that soybean hay of very high quality is slightly superior to alfalfa hay. Feeding experiments at

the South Dakota station indicate that soybean hay is 6 per cent more efficient for milk production and 7.8 per cent more efficient for butterfat production than good-quality alfalfa hay. Alfalfa and soybean hays were fed to dairy heifers at the Ohio station. Because the animals refused to eat the coarse stems of the soybeans, those receiving alfalfa consumed more feed than those receiving soybean hay, and the animals in the alfalfa-hay group made greater gains in all body measurements than those receiving soybean hay. The average daily gains in live weight, however, were 1.37 pounds for the cattle fed alfalfa hay and 1.43 pounds for those fed the soybean hay. The results indicate that where legume hays are available to growing heifers it is not necessary to supplement corn with concentrated proteins.

SOYBEAN HAY FOR BEEF CATTLE

At the Arkansas station soybean hay was compared with alfalfa hay for fattening steers. The steers fed alfalfa hay made an average daily gain of 2.50 pounds per head, while those fed soybean hay made an average daily gain of 2.41 pounds per head. A little less feed was required per unit of gain by the steers receiving alfalfa hay.

SOYBEAN HAY FOR HORSES AND MULES

Practical experience has shown that rations of soybean hay and corn, or soybean hay, corn, and oats, are very satisfactory for work horses. Soybean hay has also been found to be an excellent roughage for fattening mules. Horses and mules, when fed on soybean hay, finish with exceptionally smooth coats. No ill effects have been reported from the feeding of this hay, and such animals endure heat well. Results obtained at the Illinois station indicate that soybean hay when properly supplemented is a satisfactory roughage for growing draft fillies and that it is equal to alfalfa for this purpose. Soybean hay for horses and mules should be well cured and should not make up more than one-half of the total roughage.

SOYBEAN HAY FOR SHEEP

In a study of the relative values of red-clover hay and soybean hay for fattening lambs, the Iowa station found that soybean hay had a somewhat higher feeding value than red-clover hay. Considerably less shelled corn and hay were consumed by the lot receiving the whole soybean hay than by the lot receiving red clover, but when ground soybean hay was fed in comparison with red-clover hay the reverse was true. Over 20 per cent of the whole soybean hay was refused, but there was practically no waste from the red-clover hay or from the ground soybean hay. Results obtained by the Indiana station, comparing clover hay and soybean hay for fattening lambs, showed that the lambs fed soybean hay made more rapid and profitable gains than those fed clover hay. In experiments at the Illinois station shelled corn and alfalfa hay proved somewhat superior to shelled corn and soybean hay for fattening western lambs, the former ration resulting in slightly greater gains and in lower feed consumption for 100 pounds of gain. In a comparison by the Illinois station of alfalfa hay and soybean hay for

feeding pregnant ewes and lambs, there was no apparent injurious effect from the soybean hay. The gains made by the lambs fed soybean hay were comparable to those made by the lot fed alfalfa, although somewhat more hay was consumed by the lambs fed soybean hay.

SOYBEAN HAY FOR SWINE

The feeding of soybean hay to hogs is practiced in some sections, the crop being cut when the beans are fairly well matured and then stacked for feeding during the winter months. At the Arkansas station soybean hay was compared with tankage for wintering brood sows. Gilts receiving soybean hay with corn farrowed especially good litters, while only one gilt in the lot receiving corn and tankage farrowed a satisfactory litter. These results indicate that soybean

FIGURE 8.—The soybean is an excellent crop to pasture with hogs, supplementing the corn ration

hay was not responsible for previous trouble with abortion which has been occurring with animals receiving this roughage.

SOYBEAN HAY FOR POULTRY

Practical experience indicates that soybean hay makes an excellent winter feed for poultry, and will increase egg production. In some instances the soybeans are cut when the pods begin to form and are carefully cured to avoid loss of leaves. The practice in general, however, is to cut soybeans for hay when the seed is one-half to three-fourths grown.

SOYBEANS FOR PASTURAGE

The soybean can be utilized to advantage as pasture for all kinds of livestock. Perhaps the most profitable method is to pasture with hogs, supplementing with a corn ration. (Fig. 8.) Pasturage is especially desirable when harvesting is interfered with by weather

conditions, lack of labor, or other causes, and when the crop is grown for soil improvement. Soybeans furnish a very satisfactory pasturage in late summer and early fall when perennial pasture may be short. Soybeans grow well with corn, and the two crops may be pastured down as is often done with corn alone. Soybeans may be planted in alternate rows or mixed and drilled in the same row with corn. In case it is desirable to prolong the grazing period, varieties differing in maturity may be sown, or the same variety may be sown at different dates.

SWINE ON SOYBEAN PASTURE

The soybean is an excellent crop for supplementary hog pasturage throughout the Corn Belt and most of the Cotton Belt States. It being a legume, many farmers consider the increase in fertility of the soil, where the crop is grazed, equivalent to the cost of growing it. Hogs, if turned on soybeans before they are mature, will eat the leaves and pods, and the stems to some extent. To allow the beans to ripen before grazing, however, is usually considered more profitable. Soybeans have a very marked effect on the quality of pork, and under certain conditions the feeding of them will result in the production of soft pork. Extensive tests are being carried on to determine the relation between the feeding of soybeans and the production of pork.

In a series of tests to determine the value of soybeans as a forage crop for hogs, the South Carolina station found that pigs on mature soybeans and corn made faster gains than those in dry lot on corn and tankage; soybean forage produced more economical gains than the dry-lot method of feeding hogs, and pigs on soybean forage were more thrifty than those on corn and tankage. Feeding experiments at the Kentucky station indicate that it is unprofitable to hog down soybeans alone, but that it is very profitable to hog down soybeans and corn growing in the same field or to feed corn to hogs running on soybeans. In experiments at the Iowa station less standing corn was required per 100 pounds of gain when soybean forage with corn and tankage were used than when corn alone was hogged down or the corn was supplemented with tankage alone or with soybean forage alone. The best results in the 1924 experiment in hogging down corn were obtained when soybeans were grown with corn and supplemented with self-fed tankage.

At the Missouri station experiments showed that hogs grazing corn and soybeans produced more pork per acre, made more rapid gains, and required less feed per 100 pounds gain than did hogs grazing corn alone. More pork was produced per acre, gains were more rapid, and less feed was required per 100 pounds gain with corn and tankage than with corn and soybeans. The corn-and-tankage combination produced more pork per acre and resulted in more rapid gains with a smaller feed requirement per 100 pounds increase in live weight than did the combination of corn, soybeans, and tankage, indicating that soybeans will not entirely take the place of tankage if planted in corn to be hogged off. The one year's test indicates that when a mineral mixture composed of wood ashes, superphosphate (acid phosphate), and common salt is added to corn and soybeans, the ration is superior to corn and soybeans

alone, but not equal to corn and tankage or to corn, soybeans, and tankage.

The Ohio station conducted tests in which five varieties of soybeans were grown in separate plots of corn and hogged down. Although no difference was found in the chemical or physical properties of the varieties to which a difference in palatability could be attributed, the varieties ranked in the following order according to their palatability: 1, Midwest (yellow); 2, Hamilton (brown); 3, Manchu (yellow); 4, Ebony (black); and 5, Wilson (black).

SHEEP ON SOYBEAN PASTURE

Pasturing soybeans and corn with sheep is a common practice throughout the Corn Belt States. (Fig. 9.) This combination not only furnishes feed for preparing lambs for market, but also for

FIGURE 9.—Pasturing soybeans and corn with sheep is a common practice in the Corn Belt States

breeding ewes. Sheep will eat the weeds, soybeans, and corn leaves before touching much of the ear corn.

POULTRY ON SOYBEAN PASTURE

At the New Jersey station it was found that soybeans provided a continuous supply of succulent green feed during late summer and early fall, and that owing to their luxuriant growth they produced a liberal amount of shade for the growing chickens.

SOYBEANS FOR SILAGE

Although the use of soybeans alone for silage has not been recommended, more recent experiments indicate that a high-protein crop, if wilted to a proper degree of moisture content and tightly packed, may produce a satisfactory silage.

The soybean is, however, a valuable supplement to corn for silage (fig. 10), about 2 or 3 parts corn and 1 part soybeans making

a well-balanced silage that keeps well, is readily eaten by stock, and produces no bad effects in the quality of milk and its products. Corn alone is an unbalanced ration and should be supplemented with feeds richer in protein. Many feeding experiments with dairy cows indicate but little difference in value between corn-soybean silage and corn silage alone. The corn-soybean silage, however, has been a very popular one, and some recent experiments have shown its superiority to corn silage. Experiments were conducted at the Arkansas station from 1917 to 1924 to determine the advantage of mixing soybeans and cowpeas with corn and cane in making silage for feeding beef and dairy cattle. From the results of all experiments it was concluded that the mixing of legumes with corn or cane produces an ensilage that keeps well and is more palatable than ensilage made

FIGURE 10.—The soybean forms a valuable supplement to corn for silage

from corn or cane alone. Such mixtures were also more valuable pound for pound for milk and butterfat production and for beef production than corn or cane silage alone. In feeding investigations for milk production at the Pennsylvania station, ensilage composed of one-third soybeans and two-thirds corn by green weight had a slightly higher feeding value for milk production than corn silage.

The Maine station in an experiment with dairy cows found that the cows on corn-soybean silage with 1 pound less grain did practically as well as on corn silage. In comparing the feeding value of soybean hay and soybean ensiled with corn, at the rate of 1 part of soybeans to 2 parts of corn, at the Ohio station, an advantage of 3 per cent in feeding value was indicated for the corn-soybean silage. At the Iowa station a test of the comparative value of corn silage and corn and soybean silage showed 1.9 per cent in favor of the latter

when based on the quantity of milk produced. Steer-feeding experiments at the Mississippi station showed average daily gains of 1.99 pounds for the lot on corn silage as compared with 2.15 pounds for the lot on the corn and soybean silage, but the former lot was a little better finished.

SOYBEANS FOR SOILAGE

The soybean has an important place among soiling crops (fig. 11), and having a high content of protein, may be fed to good advantage with crops that are low in protein, such as corn, Sudan grass, and millet. The range in maturity of different varieties or that which results from the planting of the same variety at different dates makes it possible to have a succession of green forage throughout the summer and fall. When the soybean has become established it grows well during periods of drought and often succeeds where other crops fail. The palatability of the soybean at all stages of development and the ease of handling the crop also make it a very valuable crop for soilage.

Table 6 shows the digestible nutrients in 100 pounds of the fresh, green roughage of the soybean compared with other crops commonly used for soilage.

TABLE 6.—*Analyses of green forage of soybeans and other crops* [1]

Crop	Moisture	Ash	Crude protein	Carbohydrates		Fat or ether extract	Digestible protein	Digestible carbohydrate equivalent [2]
				Crude fiber	Nitrogen-free extract			
Soybean	75.1	2.6	4.0	6.7	10.6	1.0	3.1	12.2
Cowpea	82.5	2.5	3.4	4.0	7.1	.5	2.6	8.8
Corn fodder (dent, mature)	73.4	1.5	2.0	6.7	15.5	.9	1.1	16.6
Alfalfa	72.9	2.6	4.7	8.0	11.0	.8	3.6	12.8
Kafir	73.0	2.0	2.3	6.9	15.1	.7	1.5	16.3
Red clover	70.8	2.1	4.4	8.1	13.5	1.1	2.9	16.4

[1] Analyses compiled by the Bureau of Chemistry and Soils.
[2] The carbohydrate equivalent shown is the sum of the digestible crude fiber and nitrogen-free extract plus 2.25 times the digestible fat.

At the Massachusetts station, in a series of soiling experiments with milk cows, favorable results both as regards yield and composition of milk were obtained from the summer feeding of crops, particularly soybeans fed with brewers' grains.

In a soiling experiment with milk cows at the Iowa station, the results in general indicate the importance of feeding plants richer in protein than corn. The butter obtained by feeding soybean forage was of superior flavor and quality.

SOYBEANS FOR SOIL IMPROVEMENT

The value of a crop of soybeans for soil improvement will depend upon the inoculation of the plants, how much of the crop is returned to the soil, and the effect of the roots upon the mechanical condition of the soil. Leguminous plants, through the aid of the root-tubercle organisms, are able to add to the available nitrogen of the

soil and therefore are extensively used in restoring soils that are deficient in this element. Soybean plants with an abundance of nodules obtain from two-thirds to three-fourths of their nitrogen from the air and the remainder from the soil. If the soil is abundantly supplied with nitrates, the soybean will obtain most of its nitrogen from the soil rather than from the air. The fertilizing value of a crop of soybeans compares favorably with that of other legumes commonly grown for green manure.

According to investigations at the Ohio station, the average weight of the roots and stubble of the soybean was only about 10 per cent of the hay crop removed. The nitrogen left in the soil in the roots and stubble was about 6 pounds per acre, and that removed in the hay was about 128 pounds per acre. This indicates that little nitrogen is left in the soil through the roots and stubble, but when the soybean is harvested for seed a very large percentage of the

FIGURE 11.—A fine growth of soybeans to be used for soiling

leaves, often amounting to one-third of the total weight of the tops, is left on the ground.

As a soil-improvement crop, the soybean can not be expected to be effective in adding to the fertility of the soil if the entire crop is removed and none of it returned in the form of straw, green manure, or animal manure. On certain types of soil, however, especially sandy soils, increased yields of subsequent crops have resulted even where soybeans were harvested as hay or beans. At the Virginia station, experiments showed that where soybeans were cut for hay the yield of wheat was increased 3.5 bushels per acre over that where no soybeans were grown. When the entire soybean crop was turned under for green manure the yield of wheat was 6.6 bushels per acre more than when the soybeans were cut for hay. If the soybean crop is harvested for beans and the vines left on the ground, the yield of the succeeding crop will be increased more than when the crop is cut for hay, but not so much as when the entire crop is turned under.

Table 7 shows the fertilizing constituents of the roots, stems, leaves, pods, and seed of the Midwest variety cut at different stages of maturity.

TABLE 7.—*Fertilizing constitutents of Midwest soybeans cut at different stages of growth* [1]

Portion of plant and stage of growth	Nitrogen	Potash	Phosphoric acid
Roots:	*Per cent*	*Per cent*	*Per cent*
Full bloom	1.40	0.60	0.32
Seed one-half grown	1.05	.50	.26
Seed full grown	.96	.47	.22
Seed mature	.64	.22	.11
Stems:			
Full bloom	1.83	1.21	.46
Seed one-half grown	1.80	.91	.41
Seed full grown	1.08	1.17	.26
Seed mature	1.01	.58	.22
Leaves:			
Full bloom	3.59	1.28	.56
Seed one-half grown	3.18	.97	.50
Seed full grown	2.16	.75	.34
Pods:			
Seed one-half grown	3.56	2.12	.87
Seed full grown	1.29	1.90	.26
Seed mature	1.25	1.23	.25
Seed:			
Seed one-half grown	5.95	1.80	1.28
Seed full grown	6.51	1.82	1.36
Seed mature	6.37	1.89	1.38

[1] Analyses made by the Bureau of Chemistry and Soils.

The Kansas station reports an increase of 14 bushels of corn to the acre where corn followed soybeans in alternate years, as compared with corn grown continuously. At the Arkansas station, soybeans used as green manure gave nearly as good results as cowpeas, as determined by subsequent crops of wheat, oats, cotton, and corn. Soybean vines plowed under resulted in a larger yield of cotton than cowpea vines, but cowpea stubble gave a larger yield than the soybean stubble. With corn, cowpea stubble and soybean stubble gave about the same results, while the soybean vines gave better results than the cowpea vines. Experiments at the New Jersey station to determine to what extent the nitrogen supply of the soil can be maintained by growing a legume between the main crops of the rotation showed that wheat following a nonlegume yielded at the rate of 9 bushels of grain and 1,040 pounds of straw to the acre and wheat following soybeans as a green manure yielded at the rate of 17.33 bushels of grain and 2,540 pounds of straw. Rye following a nonlegume produced 15.33 bushels of grain and 1,540 pounds of straw, and, following soybeans, 21.66 bushels of grain and 2,780 pounds of straw. Following a nonlegume, the nitrogen in the dry matter of both the grain and straw amounted to 17.92 pounds per acre for wheat and 23.15 pounds for the rye, as compared with 39.13 pounds and 40.7 pounds, respectively, when grown after soybeans.

It is hardly practicable to grow soybeans for green manure alone, as they are too valuable a crop to plow under for soil improvement except under certain conditions; but in some sections they may follow wheat or oats and make sufficient growth to add considerable organic matter to the soil for winter wheat or for other fall-sown crops. For the best results as a green manure, soybeans should not

be allowed to become too mature before being turned under. Immature vines decay more rapidly, and less soil moisture is consumed when the crop is turned under early than when the dry stalks are turned under. When the plant has reached the blossoming stage most of the nitrogen has been gathered and the soybean plant decays rapidly in the soil.

SOYBEAN STRAW

The straw obtained from threshing soybeans has value as roughage for all kinds of livestock. In many sections where this crop is grown extensively for the beans the straw is baled at the time of threshing and sold in the immediate locality to stock feeders.

FEEDING VALUE OF SOYBEAN STRAW

Soybean straw has been found of value as roughage for wintering dry dairy cattle and beef cattle, and it is also good for sheep. It may be fed like other straws, and supplemented by a small grain ration. Table 8 gives the digestible nutrients of soybean straw as compared with those of other roughages.

TABLE 8.—*Analyses of soybean straw in comparison with other roughages* [1]

Roughage	Moisture	Ash	Crude protein	Carbohydrates		Fat or ether extract	Digestible protein	Digestible carbohydrate equivalent [2]
				Crude fiber	Nitrogen-free extract			
Soybean straw	8.7	7.4	5.7	34.6	41.1	2.5	2.8	41.2
Wheat straw	9.6	4.2	3.4	38.1	43.4	1.3	.4	37.2
Oat straw	9.2	5.1	4.0	37.0	42.4	2.3	1.2	40.3

[1] Analyses compiled by the Bureau of Chemistry and Soils.
[2] The carbohydrate equivalent shown is the sum of the digestible crude fiber and nitrogen-free extract plus 2.25 times the digestible fat.

The results obtained in a series of experiments at the Ohio station, comparing corn stover and soybean straw for fattening lambs when fed with shelled corn and linseed meal, show that soybean straw produced 6.6 per cent greater gains on a smaller quantity of feed per 100 pounds of gain than did corn stover. The Tennessee station compared soybean straw and corn stover as roughage in the production of milk and butter and found the ration containing soybean straw to be superior to that containing corn stover. This ration produced more pounds of milk and butterfat, and produced them more cheaply, than the corn-stover ration. In every case there was less loss in milk and butterfat during the feeding of soybean straw than during the feeding of corn stover. During the last period of feeding, one lot of cows, on soybean straw, actually gained 57 pounds of milk over the preceding period on corn stover.

FERTILIZING VALUE OF SOYBEAN STRAW

Although soybean straw is more generally used for feeding, in some cases it is used for spreading on the land for its fertilizing value. The better plan would be to feed the straw if animals are available and apply the manure to the soil. When a special bean

harvester is used the vines are left standing and later are turned under. Analyses of plants from which the seed had been gathered by these harvesters show 1 ton of this straw to contain 10.1 pounds of nitrogen, 2.1 pounds of phosphoric acid, and 17.6 pounds of potash. When soybeans were grown for seed production in citrus and pecan orchards, the straw left after harvesting with the bean harvesters was turned under and gave excellent results in soil improvement. Table 9 gives the fertilizing constituents of soybean straw compared with other common straws.

TABLE 9.—*Fertilizing constituents of soybean straw compared with those of wheat, oats, barley, and rye*[1]

Straw	Fertilizing constituents in 1,000 pounds		
	Nitrogen	Phosphoric acid	Potash
	Pounds	*Pounds*	*Pounds*
Soybean	9.0	1.2	8.9
Wheat	5.0	1.3	7.4
Oats	5.8	2.1	15.0
Barley	5.6	1.8	12.0
Rye	4.8	2.8	7.9

[1] HENRY, W. A., and MORRISON, F. B. FEEDS AND FEEDING. Ed. 18, 770 p. Madison, Wis., 1923.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

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